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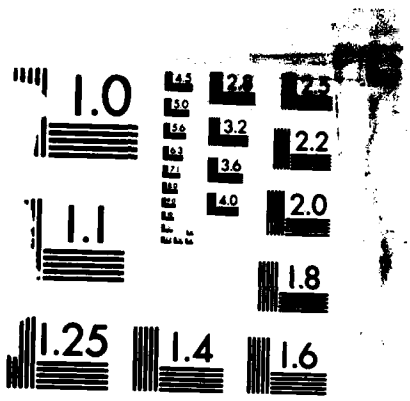

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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Cont'd

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A fracture mechanics approach was used to study crack propagation. The following results have been obtained:

Fracture mechanics is applicable to both high and low density polyethylene at low and intermediate stress intensity factors.

Constant crack speed was found to increase with detergent concentration up to 25% Igepal CO-630.

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20. ABSTRACT CONTINUED

Williams' flow model was found to be inadequate to describe crack propagation.

An aggressive environment, which has micellar solution structure, was found to be effective in cracking compared to the one having nonmicellar structure.

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ARO 19329.3-MS

Stress Cracking of Polyethylene in Organic Liquids

FINAL REPORT

24 February 1986

U.S. Army Research Office
DAAG29-82-K-0174
(Proposal # 19329-MS)

Case Western Reserve University
Cleveland, Ohio 44106

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FINAL REPORT

A. STATEMENT OF THE PROBLEM

The aim of this project was two-fold: 1) The study of crack propagation in polyethylene immersed in detergents and other aggressive fluids, and 2) Using the results of crack propagation tests, a mechanism for environmental cracking of polyethylene is to be suggested.

B1. BRIEF OUTLINE OF THE RESULTS OBTAINED BEFORE JULY, 1985

A fracture mechanics approach is used to study crack propagation. The following results have been obtained:

1. Fracture mechanics is applicable to both high and low density polyethylene at low and intermediate stress intensity factors.

2. Constant crack speed is found to increase with detergent concentration up to 25% Igepal CO-630.

3. Williams' flow model is found to be inadequate to describe crack propagation.

4. An aggressive environment, which has micellar solution structure, is found to be effective in cracking compared to the one having nonmicellar structure.

B2. OUTLINE OF RESEARCH FINDINGS DURING JULY 1985-JANUARY 1986

Crack propagation tests have been carried out using DS-2 solution and its components as environments. It was found that methyl cellulose is the most aggressive part in the mixture. The effectiveness of cracking in diethylene triamine was found to be little. Sodium hydroxide (10%) solution in water did not cause any cracking at all.

Other liquids, such as methanol, ethanol, ethylene glycol and detergents, have also been used. From the results, which were obtained in organic liquids, it was observed that surface tension and the viscosity of the environment did not affect crack growth in a specific way. However, there was a reasonable correlation between crack speed and the solubility of the liquid in polyethylene. Liquids having a solubility parameter close to that of polyethylene was the most effective as a cracking agent.

Solution structure of the environment have been found to be very important in crack propagation studies. In the earlier reports, we suggested that micellar solutions are better cracking agents compared to those having non-micellar structure. To approve this proposal further, we used three detergent solutions, namely, 10% Igepal CO-630 in ethanol, ethylene glycol and water. We ob-

served the lowest crack speed in the ethanol solution which is not micellar. The solutions in ethylene glycol and water, which are micellar, have the critical micelle concentrations of 13% and 0.01% of Igepal CO-630, respectively. It is not surprising that we obtained the highest crack speed in the water solution because of the fact that it contains a higher number of micelles in the solution.

Xylene, which is a swelling agent for polyethylene, is soluble in Igepal CO-630, but, not in water. Thus, xylene molecules would stay in the micelles in the micellar solution. Therefore, small additons of xylene to the solution would create a better cracking efficiency, which was experimentally observed, since the micelles are locally rich in terms of xylene molecules. This is also evidence that solution structure is important in cracking processes.

A model to describe crack propagation was suggested. The model is comprised of two factors: the diffusion constant of the molecules and creep rate of the swollen material at the crack tip. These two factors control the crack growth behavior before a constant crack speed is attained. However, it is proposed that the constant crack growth rate is controlled by the diffusion constant of the aggressive molecules only. The model has been successful to predict the effect of temperature on crack propagation. Activation energies for diffusion and creep rate processes, which are experimentally observed, agree well with the ones obtained from the literature.

C. The following papers and presentations have been or will be made concerned with the results:

1. "Environmental Stress-Cracking of Low Density Polyethylene", American Physical Society, Div. of High Polymer Physics, March Meeting 1984, Detroit.

2. "Environmental Stress-Cracking of High Density Polyethylene", Amercian Physical Society, Div. of High Polymer Physics, March Meeting 1985, Baltimore.

3. "Stress-Cracking of High Density Polyethylene in Detergents", ACS Div. of Polymer Chemistry, ACS National Meeting, Chicago, September 1985.

4. "Environmental Effects on Polymeric Materials", 1985 CRDC Scientific Conference on Chemical Defense Research, Aberdeen Proving Ground, November 1985.

5. "Stress-Cracking of High Density Polyethylene in Detergents", Submitted to Polym. Eng. Sci.

6. "On the Applicability of Linear Elastic Fracture Mechanics to Environmental Stress-Cracking of Low Density Polyethylene", J. Mater. Sci., in press.

7. "Effects of Detergent Concentration on the K_I-$\dot{c}$ Plots of Low Density Polyethylene", J. Mater. Sci., to be submitted.

8. "Stress-Cracking of Polyethylene in Organic Liquids", in preparation.

9. "A New Model to Describe the Stress-Cracking Mechanism of Polyethylene", in preparation.

10. "Effects of Fracture Mechanics Test Variables on the K_I-$\dot{c}$ Plots of High Density Polyethylene", in preparation.

11. "The Effects of Temperature on Environmental Cracking of Polyethylene", in preparation.

12. "Reduction in Stress Intensity Factor Caused by Bending in the Asymmetric Tensile SEN Specimens", in preparation.

D. PARTICIPANTS

Professor C. E. Rogers, Principal Investigator (1 Jul. 84 to 31 Sec. 85) re Modification P-00003 dated 2 Aug. 84.
Dr. Hugh R. Brown, Principal Investigator (1 Sep. 82 to 30 Jun. 84).
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